a number of precise and intricate bionomic correlations result automatically from the animal's modes of reaction, mediated by a central nervous apparatus which is relatively diffuse, less centralized functionally than is that of other molluscs; the habits so expressed determine the nature of the environment in which the Chiton lives.

Full reports of these studies will be found in papers to appear in the *Journal of Experimental Zoölogy*, and in the *American Naturalist*.

[1] Contributions from the Bermuda Biological Station for Research, No. 112.
[2] cf. Crozier, W. J., These PROCEEDINGS, November, 1918.

THE NERVOUS ORGANIZATION OF A NUDIBRANCH[1]

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Having in mind the important position of the mollusca with respect to the evolutional elaboration of central nervous organs, we have sought to obtain evidence permitting a more precise statement of the functional relations between the peripheral and the ganglionic conducting pathways in a nudibranch, *Chromodoris zebra*. The absence of a shell in these animals, and certain more specific peculiarities of their construction, afford favorable conditions for such analysis. A full account of our observations is in press, to appear in the *Journal of Experimental Zoölogy*.[2]

The dorsally placed 'crown' of gills comprises in *Chromodoris* about 12 distinct plumes arising from a ridge almost surrounding the anal aperture. Each plume may contract independently. All of the plumes may also contract simultaneously, and the whole gill-crown may be concealed within a collared pocket. During the day-time, and under certain conditions of alkalinity and temperature in the seawater,[3] the plumes are extended. If a plume be lightly touched at one point, the common orm of response is constriction at that level, resulting in a slight swaying of the plume. More vigorous stimulation likewise leads to this locally confined unsymmetrical contraction, which however is now seen to spread distally from the site of activation, as a collapse and shrivelling of the plume, and is also accompanied by the downward pulling of the entire plume through the traction of muscles situated in the basal tissue of the gill-crown. Still stronger activation induces longitudinal shortening of the plume, both distally and proximally to the point of stimulation, and in the basal tissue.[4]

The polarity evident in these reactions of the single gill plumes has certain fundamental resemblances to that seen in the tentacles of sea anemones.[5] Like the latter, it pertains to other than tactile forms of activation (e.g., shading), is obliterated by magnesium sulphate anaesthesia, and persists in all its aspects in the plumes of an excised gill-crown (tied off basally to preserve internal pressure). It is therefore a local matter, conditioned by a self-contained nervous structure which conducts impulses more easily distalward than basally. The nature of this autonomous nervous equipment is defined by the fact that strychnine, in concentrations amply sufficient to affect certain other responses of the nudibranch known to be mediated by the central nervous ganglia, is without influence upon the responses of the gill plumes. The type of nonsynaptic conducting mechanism (nerve net) which is thus indicated for the gill crown, we attribute, on similar evidence, to all the peripheral parts of *Chromodoris*.

If the oral tentacle of one side of a *Chromodoris* be stimulated, the homolateral dorsal tentacle ('rhinophore') contracts together with the activated tentacle; the opposite oral tentacle does not respond. If however a 'rhinophore' be stimulated, the tentacle of the same side does not react with it, nor does the other 'rhinophore' respond. The same homolateral nature and irreciprocal character of nervous transmission between the several reacting parts is further found in a detailed study of the activities of the mouth and protrusable pharynx, tentacles, 'rhinophores,' and the anterior edge of the foot. Conduction such that a 'rhinophore' responds when its homolateral tentacle is stimulated disappears when the supra- and suboesophagal ganglia have been removed.

Under the influence of injected strychnine solution, we find that these reactions involving central, inter-organ transmission are profoundly modified. In general, the threshold for such reactions (now followed by a relatively long 'refractory interval') is lowered, the responses themselves enhanced. The irreciprocal character of the conduction, as between tentacle and 'rhinophore,' is abolished; so likewise is the normally pronounced homolateral bias of the reactions obliterated. There are other additional evidences of facilitated intraganglionic communication under strychnine. These effects are not manifest in deganglionated individuals treated with strychnine.[6, 7]

It may therefore be assumed that peripherally, in the body wall and its projecting outgrowths, there are nerve-nets concerned with local responses; that these nets are characteristically polarized; and that they are dominated by the central nervous system of the nudibranch, the latter

being essentially a synaptic system. It would appear that that primitive type of nervous organization predominantly present in such coelenterates as the sea-anemones, but preserved in vertebrates only among certain autonomous internal organs,[5] still forms in molluscs a highly important feature of the animal's action system.[8]

[1] Contributions from the Bermuda Biological Station for Research, No. 113.

[2] Crozier, W. J., and Arey, L. B., "Sensory reactions of Chromodoris zebra," *J. Exper. Zoöl., Phila.*, (in press).

[3] Crozier, W. J., 1919, *J. Gen. Physiol., Baltimore*, **1**, No. 6.

[4] For more detailed treatment of the complex conditions here entering, consult papers cited in footnotes two and three.

[5] cf. Parker, G. H., 1919. *The Elementary Nervous System.* (Philadelphia.)

[6] Frölich (*Zs. Allgem. Physiol., Jena*, **11**, 1910, p. 269) had already demonstrated that in *Aplysia* the site of action of strychnine is the 'cerebral' ganglion.

[7] Cushny (*Quart. J. Exp. Physiol., London*, **12**, 1919, p. 153) points out that the depression of the reflex thresholds, rather than, as often held, the conversion of 'inhibition' to 'activation' (where reciprocal innervation is involved), is the essential feature of the strychnine effect.

[8] This conception of the nervous organization of *Chromodoris* agrees with the opinion held by Bethe respecting *Aplysia*, but the evidence here relied on is much more complete (cf. Bethe, *Allgem. Anat. u. Physiol. d. Nervensystems*, Leipzig, 1903).

ARE GENES LINEAR OR NON-LINEAR IN ARRANGEMENT?

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As to the question whether the genes in a linkage system are linear or non-linear in arrangement, Morgan and his associates[1] still maintain their former view that the arrangement is strictly linear. I have questioned the validity of this view on the following grounds.[2] (1) The forces which link the genes together are possibly molecular rather than mechanical. If so, it is doubtful whether the entire system consists of a simple thread-like chain. (2) Construction of a model in three dimensions of the relations of the genes in the sex chromosome of *Drosphila ampelophila* as shown by the data of Morgan and Bridges,[3] and on their own assumption that distances are proportional to cross-over values, proves that the arrangement can not be linear. A similar reconstruction for the sex-linked genes of *D. virilis* shows the same thing for that species even more emphatically. (3) The linear hypothesis makes necessary the further assumption that cross-overs greater than 50% occur within the linkage system.